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TITANIUM ALLOY INTEGRATED CENTRIFUGAL IMPELLER 5 COORDINATE COMPUTER ASSISTED MANUFACTURING TECHNOLOGY

by

Dianzhong Wen, Youlin Bao, Zhongshu Ren

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AUTHOR: Wen Dianzhong, Bao Youlin, Ren Zhongshu

In a cooperation between the aerospace industry's No.608 Aeroengine Research Institute and the South Motive Power and Machinery Complex, there has been successful research and an associated promoting of titanium alloy integrated centrifugal impeller 5 coordinate or axis computer assisted manufacturing (TICAM5NC) technology. Along with this, in November of 1988, it smoothly went through a ministry level technology evaluation. As far as the successful research on this new item of technology is concerned, it breaks through a big stumbling block in the process of production and test manufacture of medium and small model aviation engine centrifugal gas compressors. As far as a speed up in the development of our country's medium and small model aviation motive technology is concerned, the test manufacture of high efficiency, high pressure ratio centrifugal gas compressors will lead to a serious promotional effect.

In recent decades, high pressure ratio centrifugal gas compresors, due to the fact that they possess simple structures, low cost, high pressure ratios, stable and broad operating ranges, as well as other similar good points, have already come to peoples' attention, becoming one of the principal factors in a new era for medium and small model aviation engines. On the basis of statistics, the U.S., the U.K., France, Canada, FRG, the Soviet Union, and other similar countries among today's advanced aviation nations have only 24 types of medium and small aircraft propulsion systems which have opted for the use of centrifugal gas compressors. Medium and small model aviation engines possess clear and special advantages, which makes this realm more and more beneficial in a wider and wider area. The world's aviation engine manufacturing enterprises, at the same time as they were developing high power engines, were striving with each other to develop medium and small model aviation engines, and to develop the key problem of medium and small model aviation engines which lies in the development of high pressure ratio, high efficiency centrifugal gas compressors.

Due to the complex nature of the geometrical configuration of the formed surfaces of impellers, the uniformity of their integrated precision, their excellent interchangability, and maintainability, as well as other similar requirements, the processing or machining of aviation engine centrifugal gas compressor impellers is just relatively complicated. Once the errors between blades are too large, when

they are installed in new aircraft and later maintained or replaced, there will be an increase in the amount of work on the complex balancing assembly even to the point of there being no way to assemble it. What is still more important is the fact that this will influence the gas compressors' aerodynamic characteristics and efficiency. The machining or processing difficulty level is even greater for high pressure ratio, high efficiency centrifugal gas compressor impellers. Centrifugal gas compressor impellers are of a high load, integrated type. The impeller blade configuration must necessarily be designed to be a hyperbolic curved surface in a twisted or distorted curved space. Because of this, the design of the aerodynamic form of the surfaces is extremely complicated. The degree of difficulty of the machining or processing of the outline of the surfaces as well as the degree of precision required are quite high. In addition to this, modern, advanced small and medium aviation engines have high speeds of revolution and their gas compressor ratios of overall pressure increase are relatively high. This type of operating environment, for the materials in centrifugal impellers raises requirements even higher. Because of this, one sees the appearance of titanium alloy centrifugal impellers. As everyone knows, titanium alloy industrial technology cutting characteristics are quite bad. During the machining process, due to the fact that titanium alloy materials can easily produce elastic distortions, machining or processing dimensions are not easy to maintain, knife breaking phenomena are serious, vibration is a relatively great problem, as well as other similar problems. The use of normal processing or machining methods basically have no chance of working. It is necessary to make use of a high precision, modern 5 coordinate numerical control machine tool. Only then is it possible to complete the work. Because of this, one then started the development of computer assisted manufacturing (CAM) as well as numerical control (NC) technologies.

The various industrial nations of the world have shown great interest in starting CAM and NC technology development. Entering the 1970s, CAM and NC technology development was rapid. Industrially advanced countries have made quite sizable investments in this area. In only 1983, the U.S. sales of this type of technology reached 17.16 billion U.S. dollars. Japan reached 1200 billion yen. The European

joint investment was 8.4 million British pounds. The FRG investment was 2 million U.S. dollars in order to support this type of technology. Among these countries, one has seen a continuing appearance of CAM and NC 3-5 coordinate numerical control software installed everywhere. Due to the fact that these enterprises and companies see CAM technology as a core secret, not only do they not announce it, but they do not sell it either. Because of this, up to the present time, there are still only a small number of countries which have a hold of these technologies.

In our country, CAM and NC technologies began to develop in the 1970s. However, the majority of the software was smaller than three axis software when development began. Multiple axis (three coordinate or more) numerical control made a breakthrough in the aviation industry. However, in the engine industry, before 1988, there was still no set of CAM systems that could supply processing or machining for the various types of centrifugal impellers. In order to shrink the distance between our country and the advanced countries in the area of centrifugal gas compressor manufacturing technology, we broke through the gas compressor integrated impeller and centrifugal impeller predicament. In 1983, we formally set up the titanium alloy integrated centrifugal impeller CAM project team, engaged in the development of research on computer programs and industrial technologies. The person responsible for this project was Wen Dianzhong. The principal personnel participating were Bao Youlin, Chen Guozhi, Chen Ji, and Li Shulin. They made wideranging technological adjustments, verifications, and careful designing on the basis of a certain amount of borrowed processing technology. At the beginning of 1986, the software was comprehensively adjusted and completed. This software, on the Xian Aviation Engine Company H6-C 5 coordinate numerical control machine tools, was run against an empty load. The results were excellent. In September of the second year, this software was turned over to the South Motive Power and Machinery Company's MC-B74ATC processing center. With the close cooperation of all the personnel, the software went through unceasing improvements and corrections. At the end of 1987, it smoothly completed an aluminum impeller test processing. The precision of the processing was very good. In June 1988, it completed a titanium alloy (TC11) integrated centrifugal impeller processing. Checking out the

precision of the surfaces formed, they corresponded completely to the design requirements, achieving the same type of product level found internationally.

Fig. 1 A Titanium Alloy Integrated Centrifugal Impeller Processed Making Use of TICAM5NC Machining

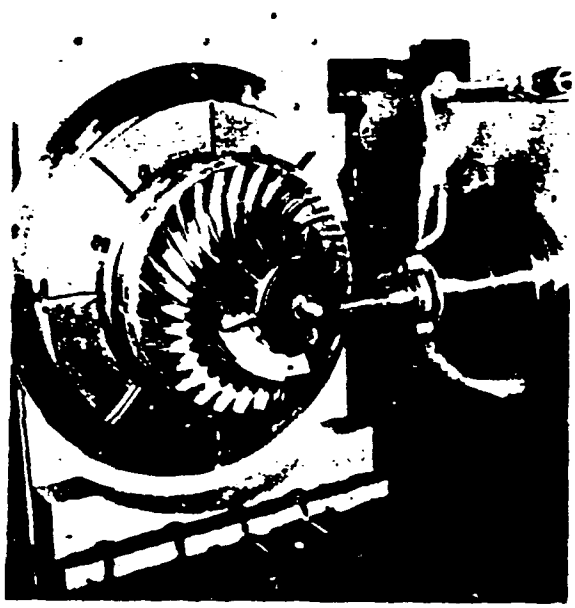

Fig. 2 A Titanium Alloy Integrated Centrifugal Impeller in the Process of Machining

Fig. 3 Titanium Alloy Integrated Centrifugal Impeller Finished With Processing on the MC-B74ATC 5 Coordinate Machine Tool (Right)

The principal contents and keys to TICAM5NC technology are:

1. 5 coordinate numerical control processing software, to include: various types of processing programs for knife position calculations (also called preset programing). This primarily determines, given controled conditions, the points, lines, and surface knife positions as well as movement tracks. This is the main part of TICAM5NC software. Universal postset processing programs principally resolve automatic composition problems and problems related to the universal use of programing in any machine tool. As far as computer graphics technology is concerned, on the computers, it is not possible to develop the impeller machining or processing states on the revolving surfaces. If this were possible, this would enable one to take the various types of processing program cutting tool milling states, the states of interference between the cutting tool and neighboring impeller blades, those between the cutting tools and surfaces which are finished milling, as well as other similar states or conditions, and accurately display them on the computer terminal. The greatest limitation this reduces is the inability to develop, on a lined surface, the amounts of interference with the rod shaped milling tool. This raises the precision of the processing. The software possesses universal usability, flexibility, and is capable of appropritate use with the various types of blade surface forms (it can develop lined surfaces and any kind of free curved surface) for processing. It is able to process machining which has no small blades or one group of small blades or many groups of small blades for machining. It is able to make use of rod shaped cutting tools, tools with spherical projections or ball heads, and drum shaped cutting tools for processing. It is able to make use of the two modes of man-machine interaction and primary reliance on the machine in carrying out computer operations.

2. As far as the deciding of the design of cutting tools and the processing path is concerned, one includes a precise specification of the type of cutting tool and its geometrical configuration, a resolution of the problem of knife breakage in processing with titanium alloy, and a way of overcoming the relatively great vibration problem with titanium alloy processing.

3. As far as the selection of the parameters of processing techniques is concerned, this includes corrections for elastic deformities, adjustments of milling cut angles of cutting tools, as well as other technical parameters (such as the amount of knife cut margin, milling depth, the speed of knife entry, the length of processing steps or increments) related to the selection of adjustments.

The TICAM5NC system resolves the problems described above in a very satisfying manner. The system is made up of the four sections of tool position calculation, graphic display, tool editing, and post set or post positioning processes. This system software is totally written with the use of the FORTRAN language. Along with this, it is ported into the CAD centrifugal impeller system and is able to directly carry out CAD/CAM data transfer, realizing the creation of a single integrated CAD/CAM processing. Software goes through numerical transformations and takes knife position tracks which it is not possible to display on curved surfaces in three dimensional space and turns them into two dimensional problems. On the computer terminal, it carries out graphic processing simulations and does diagnostic checks for processing or machining interfecence. Research on this project opts for the use of scientific methods and introduces portions of advanced techniques for the processing of impellers in certain worm shaft engines. It carries out optimization calculations to minimize interference in cutting tool positions. It accurately determines the range of the cutting tool courses and technical parameters for elastic deformation corrections. Along with this, it makes use of man-machine interface methods of editing knife postions, making the control of the technical paths in the processing possess a very great flexibility. Its post set processing programs make it possible to make appropriate use of various types of 5 coordinate machine tools. As far as the smoothness of the rotary movements of the two B and C rotating plates are concerned, it carries out, in a stabilizing manner, automatic diagnostic checks. Along with this, it possesses certain capabilities to select the length of processing increments or steps as well as a Z axis tool compensation function.

Practical applications of the TICAM5NC system demonstrate that, with aluminum stock, the tolerances on blade form surfaces were less than 0.05 mm. With titanium alloy stock, the errors on blade forms were within 0.08 mm.

Compared to similar types of technology in other countries, the TICAM5NC system, in its development stage, has special functional capabilities and other similar features which all have the advantage. The French Toufumeiga (phonetic equivalent) (TM) company brought in the U.S. APTIV-SSX5A preset program and the FRG's MC-B74ATC post set program, after which they again went through several years of development. It was only after this that one saw the appearance of the first titanium alloy impeller processing. The complete set of technological developments in the TICAM5NC system, from research coordination and verification to successful test manufacture relied entirely on our own efforts. It used only something less than 5 years of time. The software system which the TM company is currently using still has no graphics capability and has no way of processing diagnostic checks. The U.S. Auto-Trol company came to China in October of 1988 promoting the newest S-7000(12) system which, although is has three dimensional graphics display, has no way to carry out multi-axis numerical control processing simulations and interference diagnoses. However, the TICAM5NC system not only has three dimensional graphics display. It is also capable of carrying out processing simulations and interference diagnostic checks. The internal processing functions of the APTIV software are relatively weak. There are no tool course calculations. By contrast, the TICAM5NC system possesses very strong internal processing capabilities. It is possible to automatically calculate out the ranges of cutting tool courses and accurately give the positions of tool advances and withdrawals. Titanium alloy elastic deformation correction problems are recognized by everyone as difficult ones. The TICAM5NC still, within relatively short periods of time, gives one complete solutions.

The TICAM5NC technology evaluation committee, composed of noted experts and professors from our country, unanimously recognizes that this piece of technology is an original creation within our country, putting us in a leading position, and achieving the international levels of the 1980s. Promotion of its widespread application, as far as the speeding up of the test manufacture of advanced medium and small aviation engines in our country is concerned, as well as in terms of resolving the difficult processing problems associated with the iron and steel, chemical engineering, petroleum, coal, and light industries ministries' centrifugal blowers, refrigeration turbines,

fluid pressure or hydraulic pumps, compressors and superchargers, as well as other similar devices, possesses very important strategic significance. Moreover, it will also produce clear economic benefits.

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